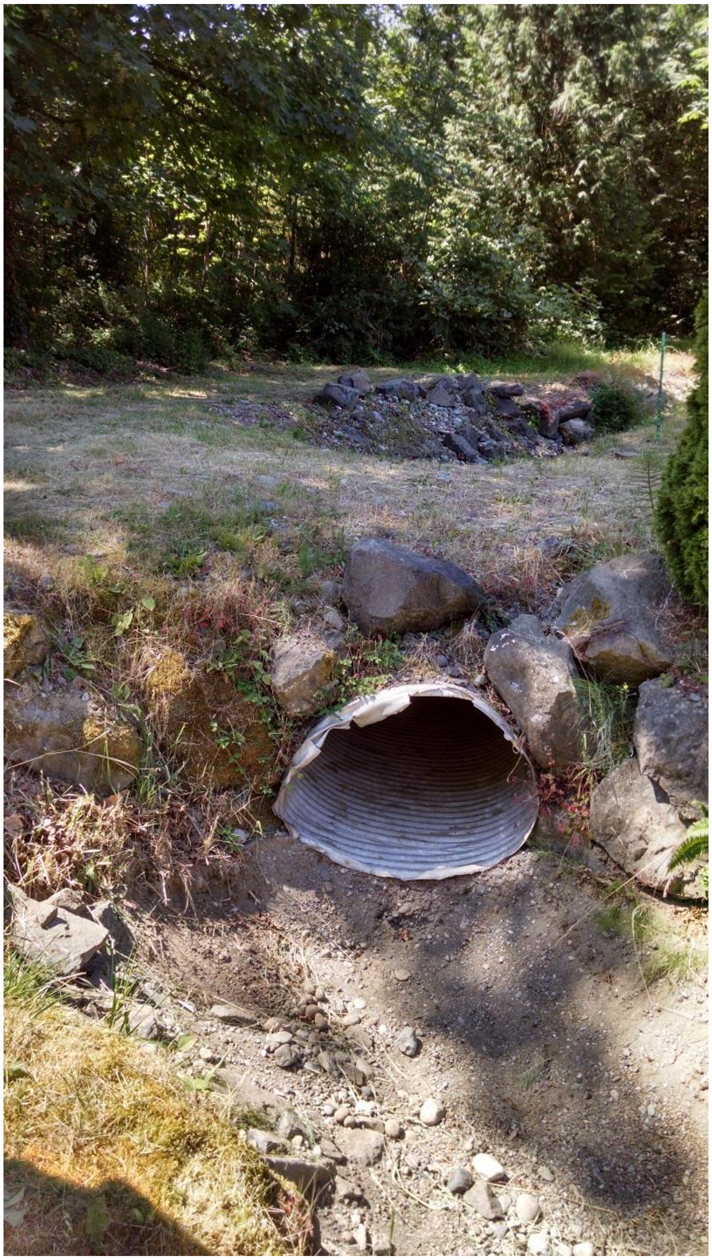

Anti-Aircraft Creek Culvert Replacement Analysis Report

50% Design Review Document

Prepared for

City of Issaquah

Prepared by

Mead & Hunt

www.meadhunt.com

October 15, 2015

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1. Introduction

A. Background

A culvert on Anti-Aircraft Creek at the intersection of Newport Way NW and NW Oakcrest Drive is vulnerable to sedimentation and has low capacity, resulting in occasional flooding of Newport Way NW. Over the last 17 years, nine rainfall events have caused plugging of the culverts, resulting in water and debris over the roadway and $60,000 in cleanup costs. In five of those events, the roadway was temporarily impassable and had to be closed to traffic.

Mead & Hunt is preparing plans, specifications, and estimates for a culvert realignment that is intended to alleviate flooding. This project is partially funded by a FEMA hazard mitigation grant. Improvements entail realigning a portion of Anti-Aircraft Creek, replacing existing undersized culverts with box culverts, and improving the channel grading. This report provides the design analysis for the culvert replacement, regrading of the stream channel, and realignment of Anti-Aircraft Creek.

B. Project Location

The Anti-Aircraft Creek culvert replacement project is located in the city of Issaquah, Washington, on Newport Way NW at NW Oakcrest Drive (at approximately 2000 Newport Way NW), which is 3,000 feet west of the intersection of Newport Way and SR-900. The location where Anti-Aircraft Creek crosses Newport Way is 47.547059° -122.070503°. The project location is shown in **Figure 1**.

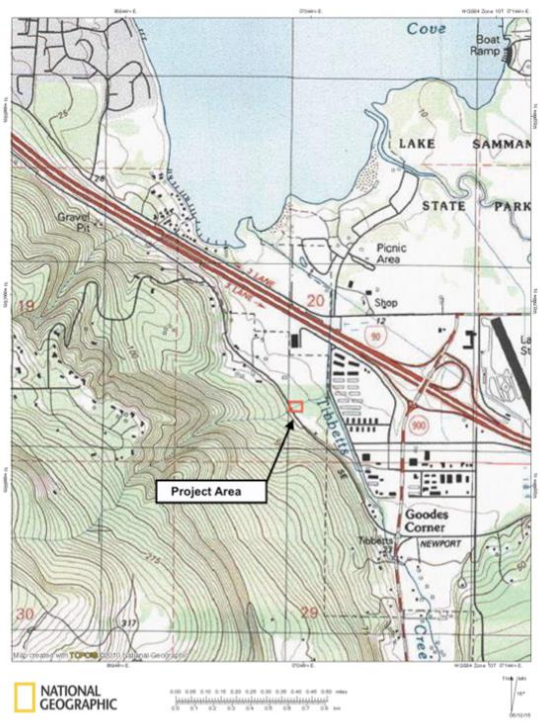

Figure 1. Project Location

Newport Way is a two-lane minor arterial that traverses the northern base of Cougar Mountain, parallel to I-90. Anti-Aircraft Creek is a small Class 3 stream, which is considered a non-fish bearing stream, that originates near the top of Cougar Mountain (near where a 1950s missile base was located) and discharges to a wetland. The wetland appears to drain toward Tibbetts Creek but a "distinct upland berm is present between the Creek's floodway channel and the wetland."[1] The tributary basin of Anti-Aircraft Creek is partially developed with low-density rural development to the northwest. The remainder of the basin includes Cougar Mountain Regional Wildland Park and undeveloped vacant lands.

C. Project Goals

The objective of this project is to realign a portion of Anti-Aircraft Creek, a channelized stream, where it crosses NW Oakcrest Drive and Newport Way NW. These improvements will eliminate two 90-degree bends, a 165-foot long flat section, and several undersized culverts that were built as part of land development activities several decades ago. The improvements will also prevent the system from getting filled with stream sediment during major rainfall events because the alignment will be straightened and sloped at sufficient grade to allow natural sediment transport. The project will eliminate a recurring and costly maintenance problem for the City of Issaquah and associated hazards to motorists who travel on Newport Way.

Specifically, the goals of this project is to:

1. Increase velocities to reduce sediment deposition.
2. Eliminate 90-degree bends present in the existing system.
3. Reduce overall length of culvert.

Although this section of Anti-Aircraft Creek is considered a non-fish bearing stream, a supplemental goal is to include fish passable elements in accordance with Washington Department of Fish and Wildlife (WDFW) where feasible.

D. Project Description

The Anti-Aircraft Creek Culvert Replacement Project includes channel modification and installation of a box culvert underneath Newport Way NW, on a City of Issaquah owned parcel directly north of Cougar Mountain Regional Wildland Park. The culvert will discharge onto parcel 2024069115, on the east side of Newport Way NW. This project will take place concurrently with a proposed residential development (Riva Townhomes) project on parcel 2024069115.

The box culvert will replace the ditch along Newport Way NW and the existing culverts and will connect back to the existing Anti-Aircraft Creek channel just west of the wetland. The culvert that is under NW Oakcrest Drive and one of the culverts under Newport Way NW will be abandoned in place. A second culvert under Newport Way NW will remain.

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[1]Wetland and Stream Determination for Issaquah Farms Property, (Parcel #042308-9029): City of Issaquah. C. Gary Schulz, Wetland/Forest Ecologist, letter dated October 14, 2014.

Approximately 127 linear feet of the existing stream channel will be filled as part of the residential development activities on the east side of Newport Way NW. Additionally, 205 linear feet of roadside ditch along the west side Newport Way NW will be filled. Disturbed areas will be graded and restored to pre-project conditions.

On the west side of Newport Way NW, prior to the inlet to the proposed box culvert, the Anti-Aircraft Creek channel will be extended and enhanced with plants and gravel, providing additional stream channel habitat. An energy dissipator will be constructed at the outlet of the box culvert on the east side of Newport Way NW. The energy dissipator will consist of a stilling basin containing large sub-angular boulders and woody debris that will dissipate the energy in a short distance and minimize downstream erosion.

Downstream of the dissipator, a section of channel will be constructed and a small transition of the existing Anti-Aircraft Creek channel will be modified and enhanced with clean streambed gravels. The channel modification is within the wetland buffer. No portion of the culvert work will occur in the wetland.

Proposed landscaping will include wetland and buffer plants that are native to the area and specific to the conditions of this setting, including those well-suited for the surrounding soils, hydrologic nature of the area, and to the amount of sunlight or shade.

E. Limitations

Along Newport Way NW, the presence of water, gas, communication, and other unknown utilities limit the location of the culvert crossing. A pothole survey was completed in 2012 by Applied Professional Services to identify the location of the existing utilities. A summary of the pothole survey is presented in Appendix A. In addition, the location of the proposed Riva Townhomes project and adjacent wetlands limit the amount of workable area. These limitations minimize design flexibility and will be discussed later in this report.

2. Data Collection

A. Existing Site Conditions

Project Site

The project site is located at the intersection of Newport Way NW and NW Oakcrest Drive. The project site extends approximately 92 feet upstream from the where Anti-Aircraft Creek first enters a culvert and extends downstream to the point of discharge to the wetland. As the stream channel approaches Newport Way NW, the flow is conveyed 19 feet through a 4.2-foot by 2.6-foot oval corrugated metal culvert. This is the point at which Anti-Aircraft Creek transitions from a steep, meandering stream channel to a flat constructed channel with a series of culverts.

The creek is then conveyed through a 165-foot-long trapezoidal channel adjacent to the southwest side of Newport Way NW until it reaches NW Oakcrest Drive. The creek enters a 2.4-foot by 3.4-foot, 82-foot-long corrugated metal culvert crossing NW Oakcrest Drive. On the north side of NW Oakcrest Drive, the creek flows for approximately 36 feet through a trapezoidal channel before it is conveyed through two 24-inch diameter concrete pipes crossing under Newport Way NW.

On the east side of Newport Way NW, the creek flows through a narrow, shallow channel along the south side of the Sammamish Pointe subdivision. The stream continues to the east as it enters the wetland, approximately 305 feet downstream of the culvert's exit. The downstream project limits was established at the wetland boundary in order to avoid construction within the wetland.

Upstream of the Project Site

Anti-Aircraft Creek originates on the northeast face of Cougar Mountain and flows down the face, reaching the project site. The upstream conditions of Anti-Aircraft Creek show a massive amount of sediment transport. Certain areas of Anti-Aircraft Creek experience high energy flows that erode the channel banks. Immediately upstream of the project area, the creek parallels NW Oakcrest Drive, to the south of a row of residential homes. During site visits conducted in spring 2015, we observed a drop of about 10 feet in the channel bed between the fifth and sixth houses located west of the intersection of Newport Way NW and NW Oakcrest Drive.

Downstream of the drop, the channel is incised with walls approximately 8 feet high and a channel width of about 4 feet. Upstream of the drop, we observed a more stable channel morphology with a much wider measured bankfull width of approximately 14 feet. The observed stable stream channel continues for about 100 yards upstream before channel incision is observed again. This incised reach is very similar to the incision downstream, continuing for about 200 feet upstream before forming back into a more stable looking stream morphology.

Downstream of Project Site

The channel of Anti-Aircraft Creek downstream of the Newport Way NW crossing is very shallow, with minimal bank heights. The stream channel is defined for approximately 65 feet after entering the wetland, where the stream transitions to subsurface flow. After 42 feet of subsurface flow, the channel reemerges in the wetland and ultimately conveys flow to the east, to Tibbetts Creek. Upstream of the wetland, Anti-Aircraft Creek is classified as a Class 3 stream (see earlier reference to Gary Schulz's letter dated October 14, 2014).

B. Watershed Conditions

The watershed for Anti-Aircraft Creek is on the north face of Cougar Mountain and is delineated as shown in **Figure 2**. The watershed was calculated to be 226 acres using ArcGIS and consists of natural forests with very little development. A couple of subdivisions have been developed adjacent to the watershed area and may have caused some adverse effects during construction. Specifically, the adjacent subdivisions may have altered the stream hydraulics to cause the stream incision that was observed.

There has been history of tree clearing on Cougar Mountain; however, there is no tree clearing currently occurring near the watershed. In addition, there are no immediate plans for further development within the watershed.

Figure 2: Anti-Aircraft Creek Watershed

C. Reference Reach

The reach directly upstream of the most upstream culvert was initially identified as the reference reach for the proposed channel downstream of the culvert crossing. However, we observed evidence of channel modifications intended to reduce flooding. As a result, the reference reach was shifted farther upstream of the project site approximately 150 feet. This reference reach exhibited channel morphology and geometry expected to historically exist in the reach section impacted by the constructed channel section and culvert crossings. The proposed channel geometry is based on the topographic sections, representative bankfull widths, and slopes of the reference reach. The data collected from the reference reach can be found in Appendix A.

3. Hydrologic Analysis

A hydrologic analysis was performed to determine the design flows from Anti-Aircraft Creek that will flow through the proposed culverts. For design, we evaluated the 100-year, 10-year, and 2-year peak flows. The 100-year flow is necessary to size the culvert to handle high-intensity storms. The 10-year and 2-year design flows are necessary for fish passage analysis. These design flows are discussed further throughout the remainder of this report.

A. Web Soils Survey

Web Soils Survey is an informational tool from the United States Department of Agriculture that can determine characteristics of the soils in a defined area of interest. For this project, the area of interest is the contributing drainage basin. The drainage basin was calculated to be 226 acres, using ARC-GIS and topography data provided by King County. Once we defined the area of interest in Web Soils Survey, the program displayed a soil map containing areas of different types of soil. For our purpose, we were only interested in learning their AASHTO Soil Classification Group. Using the mapped data, we were able to determine how much of the drainage basin contains soils from the different classification groups. The results are shown in Appendix A.

B. WWHM

To determine the design stream flows, modeling was performed using the Western Washington Hydrology Model (WWHM), Version 2012, published by the Washington State Department of Ecology. The modeling starts with defining drainage basins and connecting them to a point of compliance using different modeling capabilities.

The information needed to determine the design flows are site location, soil data, topography, and the drainage area. The model was run and a detailed hydrologic report was created. This report is presented in Appendix B. A summary of the calculated design flows for Anti-Aircraft Creek is shown in **Table 1**.

Table 1: Anti-Aircraft Creek Design Flows

Recurrence Interval	2-Year Event	10-Year Event	100-Year Event
Percent Annual Chance	50%	10%	1%
Peak Discharge	6.17 cfs	13.87 cfs	28.26 cfs

4. Hydraulic Analysis

The purpose of the hydraulic analysis is to function as the basis for the project design. The hydraulic analysis performed consisted of modeling and analyzing the existing conditions, developing a design based on the hydraulic problems and requirements, and modeling and analyzing the final design for project compliance.

A. Modeling Approach

To evaluate the hydraulic effects and impacts of this project, modeling was performed using Hydrologic Engineering Center River Analysis System (HEC-RAS) software, Version 4.1.0, published by the US Army Corps of Engineers. Comparative modeling was performed for existing conditions and proposed conditions to evaluate potential changes to floodplain water surface elevations, flood widths, and flow velocities for various flood events. The modeling effort was supported by site observations, a detailed field survey, published FEMA data, and design plans of existing structures.

B. Existing Condition Model Basis

The HEC-RAS model was created primarily by exporting surveyed data from AutoCAD Civil3D. The exported surveyed data included channel geometry, distances between cross sections, and elevations. Twenty cross sections were imported from AutoCAD Civil3D, creating the channel geometry. The location of the cross sections are spaced out approximately every 40 feet, with additional cross sections immediately upstream and downstream of culverts to properly model for contraction/expansion. Using pictures taken in the field, the Manning's n values were determined for the main channel and its floodplain. The channel upstream of the Newport Way NW crossing was primarily clean and straight with some stones and weeds, while the channel downstream of Newport Way NW consisted of more weeds, ineffective slopes, and sluggish reaches.

Once the channel geometry and properties were input in the model, the existing culverts were created based on the surveyed information. The culvert size, material, length, and invert elevations were needed for proper modeling. Once the geometric data was complete, the flows that were calculated using WWHM (see Section 3) were entered into the model with the boundary conditions. Since there is no existing measured FEMA data of water surface elevations for Anti-Aircraft Creek, the normal depth was used as the boundary condition. The upstream slope was determined to be 17% while the downstream slope was determined to be 3% using topography maps. The results of the existing conditions demonstrate how Anti-Aircraft Creek behaves throughout the current flow path and its hydraulic conditions as it enters the wetland. This information was used as a basis of design. The resulting water surface profile of the existing conditions is shown in **Figure 3**.

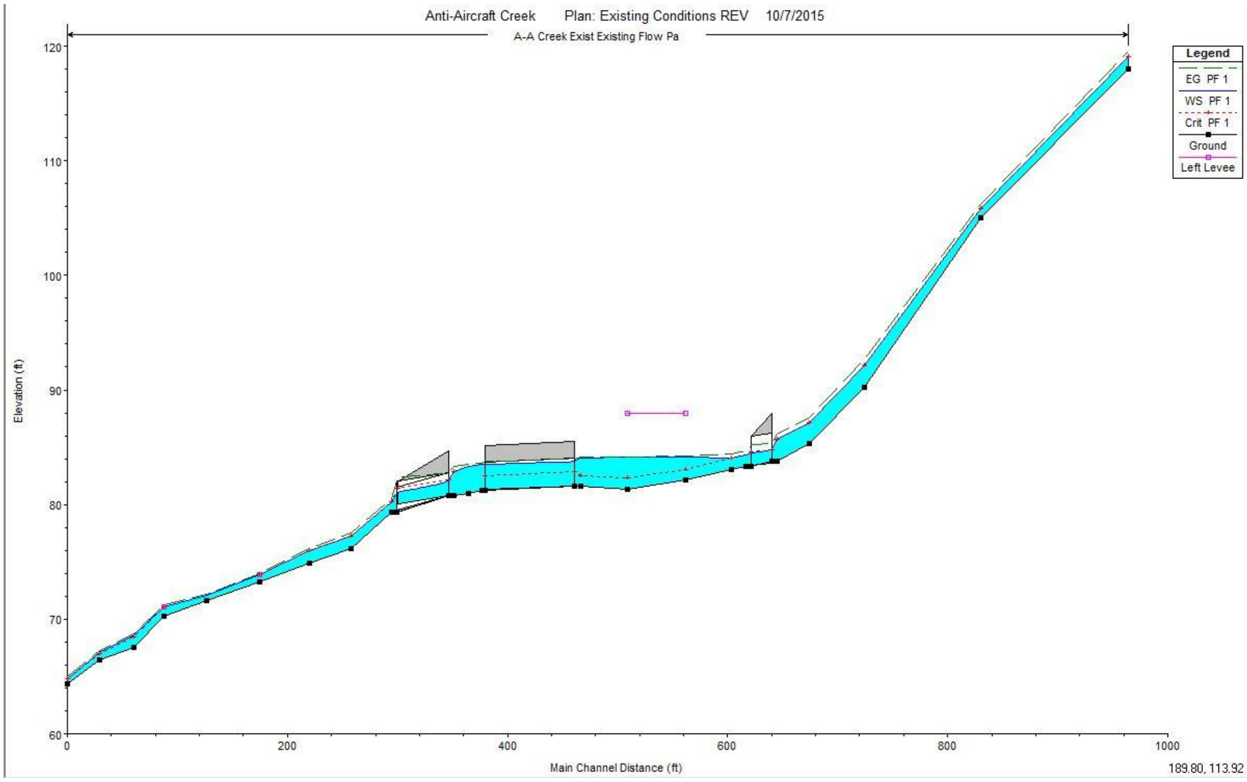


Figure 3: Water Surface Profile for Existing Conditions

C. Proposed Condition Model Basis

The proposed conditions model was developed by the same process as the existing conditions model. First, the proposed flow path alignment was determined working through the different design parameters and project constraints. Sample lines were created to export the existing geometry to represent cross sections in HEC-RAS. These sample lines contain the existing geometry, distances between cross sections, and elevations. They are placed approximately every 50 feet and immediately upstream and downstream of the culverts for expansion/contraction computations. Once the sample lines were imported into HEC-RAS, we modified the cross sectional geometry, elevations, Manning's n, and bank locations to that of our design.

The design of the proposed Anti-Aircraft Creek crossing consists of extending the existing stream channel an additional 18 feet toward Newport Way NW. Approximately 100 feet of the stream channel will be enhanced and regraded to match the channel bottom elevation to the proposed box culvert invert. The concrete box culvert is 6 feet by 2 feet and is 67 linear feet long. The proposed box culvert discharges into a culvert junction box located under the sidewalk on the downstream side of Newport Way NW. From here, the flow discharges from the junction box and enters another 6 feet by 2 feet concrete box culvert that is 71 linear feet long. The box culvert extends 4 feet past the proposed Riva Townhouses roadway and discharges into an energy dissipation structure located in the Wetland A buffer area.

A USBR Type III stilling basin was chosen to be the appropriate energy dissipation structure and was designed according to the USDOT Hydraulic Design of Energy Dissipators for Culverts and Channels. The purpose of designing the stilling basin was to ensure that a hydraulic feature can dissipate enough energy and reduce the velocity to properly discharge the flow into the proposed stream channel and ultimately into the wetland. The concrete structure works properly, but it is not in line with the natural aesthetics of the area. In order to stay with natural aesthetics, natural materials are used to mimic the geometry of the stilling basin. The length of the basin essentially stays the same; however, the basin is widened by 2 feet to help dissipate energy. The newly roughened basin consists of blocky, sub-angular boulders 3 feet to 4 feet wide and a minimum 12” diameter woody debris. See Appendix D for the roughened stilling basin calculations.

Once the stream flow passes over the end transition, it discharges into a newly designed channel. The proposed channel starts at the outfall of the stilling basin and immediately turns to the north and then curls back around to meet up with the existing stream channel. The channel was designed to be 6 feet wide as the bankfull width with a maximum depth of 2 feet. This allows the flow to stay in the channel during most storms but can reach the floodplains during heavy storms. The newly constructed channel will contain many large boulders and additional wood features to help reduce velocity and dissipate energy as it heads toward the wetland.

As the newly designed channel meets with the existing stream channel, approximately 15 feet before entering the wetland, the proposed stream will start to be formed to match the existing stream channel. At 5 feet before the wetland, the proposed stream channel and the existing channel should be completely matched.

When we were satisfied with our modelled geometry, the model was finished and ready to be run with the existing flow data. The flow data remains the same as the existing conditions model, as there is no hydrological difference between the two scenarios. The resulting water surface profile of the proposed conditions is shown in **Figure 4**.

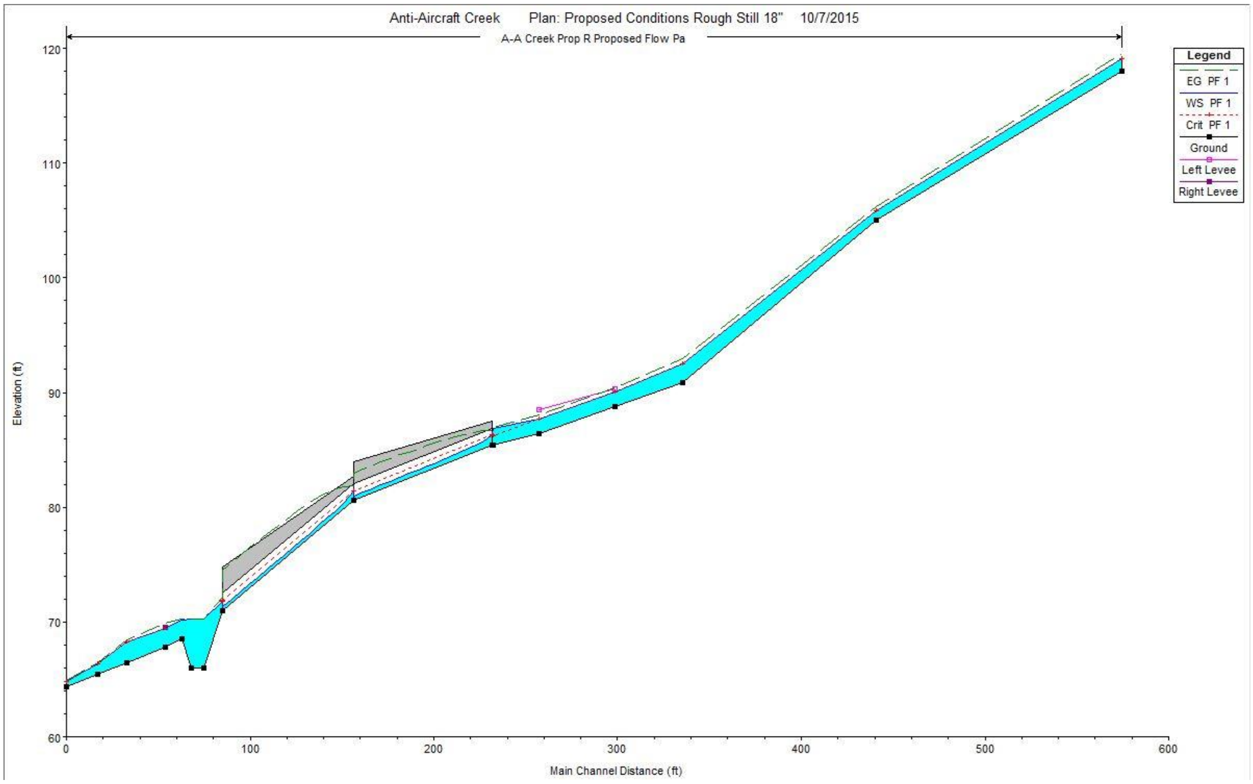


Figure 4: Water Surface Profile for Proposed Conditions

D. Results of Hydraulic Analysis

The results of the hydraulic analysis shows that the proposed culvert conveyance system has the ability to convey the 100-year design storm for Anti-Aircraft Creek. As shown, the hydraulic grade line of Anti-Aircraft Creek never overtops the crown of the culvert. In addition, the WSDOT Highway Runoff Manual states that the 100-year flow cannot overtop the roadway. However, we want to guarantee that the flow will not top the crown, as the crown will be approximately 1 foot below the roadway surface. We want a foot of free board to act as a factor of safety to ensure that the water surface will not rise above the roadway.

In addition to being able to convey the 100-year design storm, the culvert system and the regrading of Anti-Aircraft Creek increases the velocity of the flow upstream and throughout the culvert system (see **Table 2**). This is important because the underlying problem of the existing system is the buildup of sediment behind culverts. In the existing conditions, the velocity decreases from 5.54 ft/s to 1.47 ft/s as the flow travels from the culvert entrance through the flat section. This decrease in velocity is what causes the sediment to settle and build up behind culverts. For the proposed conditions, the smallest velocity calculated is immediately upstream of the proposed culvert at 5.33 ft/s. This increased velocity and grade will now be able to transport the sediment through the system.

However, as a result of the new culvert system, the discharge velocity is much higher than the existing conditions and can cause scour. We designed a roughened stilling basin consisting of big sub-angular boulders and woody debris to act as an energy dissipation structure. As the stream flow discharges from the culvert system, the roughened stilling basin reduces the velocities and energy to where the flow leaves the basin as subcritical. The subcritical flow then continues on through the newly constructed channel to meet with the existing channel and into the wetland. The results confirm that the proposed culvert system will convey the design flood flows. (See Figure 4.)

Table 2: Anti-Aircraft Creek Velocities

Anti-Aircraft Creek Velocities	
Existing Culvert Entrance	5.54 ft/s
Existing Flat Ditch	1.47 ft/s
Existing Culvert Discharge	10.59 ft/s
Proposed Culvert Entrance	5.33 ft/s
Proposed Culvert Discharge	14.32 ft/s
Proposed Stilling Basin Discharge	1.54 ft/s

E. Fish Passage Analysis

Although this section of Anti-Aircraft Creek is considered a non-fish bearing stream and the primary purpose of the project is to alleviate a flooding hazard, a supplemental goal is to include fish passable elements in accordance with WDFW where feasible. Because of the utility constraints, we are not able to provide the design velocities and depth for fish passage through the system. The main utility constraint is an existing fiber optic duct with 40 inches of cover. This constraint forces the proposed culvert to be sized to fit within the 40 inches of allowable space. As a result, the prosed culvert cannot have the required stream bedding due to the vertical limitations and the potential for debris to clog the culvert.

The existing utilities also force the slope of the culvert as such that the resulting depth and velocities will not be adequate for fish passage. The culvert entrance and discharge invert elevations are fixed due to the utility constraints, resulting in a culvert slope that is inadequate for fish passage. In addition, the design width for a stream simulation culvert would need to be approximately 16 feet wide and is not suitable for the site and budgetary constraints. A summary of the fish passage and culvert design criteria as developed by WDFW, the status of adherence with the design criteria, and additional discussion are provided in **Table 3**.

Table 3: Culvert Design Criteria

Anti-Aircraft Creek Culvert Design Criteria

Design Criteria	Satisfy Design Criteria?	Comments/Constraints
Radius of curvature for stream is recommended to be 3−4 times the channel width	Yes	The radius of curvature is approximately 3.5 times the channel width. We will armor the outside of the curve to eliminate erosion and to protect the bank as insurance.
Bankfull width less than 15 ft	Yes	The average recorded bankfull width is 11.7 ft and the max was 14 ft.
Length-to-width ratio < 10	No	The length-to-width ratios for the two culverts are 11.2 and 11.8. The culvert would need to be 7 ft wide or greater to satisfy.
Moderately confined channel	Yes	The stream channel is moderately confined.
Width of bed inside of culvert = BFW x 1.2 + 2 ft	No	The width of the culvert is 6 ft instead of the 16 ft required by the equation. Assuming reference reach bankfull width.
Countersunk culvert 30-50% of its rise	No	The proposed culverts are not countersunk due to having no bed.
Culvert bed should have a cascade or step-pool morphology	No	There is no bed inside the culvert due to the culvert size restraints. A Plunge pool at the discharge of the culvert dissipates the stream energy.
Bed structure is built in at the time of construction	No	There is no bed inside of the culvert due to the culvert size restraints.
Culvert bed slope shall be no more than 125% of the upstream channel slope	No	There is no bed in the culvert due to the constraints. The slope of the culverts are 7.01% and 12.54%. The slope of the culverts are based off design constraints rather than matching upstream channel slope.
Channel stream bed sizing	Yes	There is no bed in the culvert due to the constraints. However, the bed in the modified stream section was matched to an upstream reference reach via pebble count.
Maximum velocity for fish passage = 4.0 ft/s	No	The 2-year peak flow results in a 7.86 ft/s discharge from the culverts. The steep slope produces the high velocities. However, the slope cannot be adjusted due to geometric constraints.
Minimum flow depth for trout = 0.8 ft	No	The 2-year peak flow results show 0.13 ft flow depths within the culverts.
Maximum hydraulic drop for trout = 0.8 ft	Yes	The 2-year peak flow results show a max hydraulic drop of 0.65 ft at the outfall of the downstream culvert.

5. Sediment Transport Analysis

The deposition of sediment is one of the contributing factors that causes the clogging of culverts and the overtopping of Newport Way NW. We believe the sedimentation issue stems from upstream conditions where we observed extensive erosion and incision of the creek. Addressing upstream conditions is not in the scope of this project but may be considered at a future date.

The sediment analysis was performed to confirm that the proposed stream channel and culvert conveyance system have the capacity to transport sediment through the system. We used the shields diagram along with the streambed geometry to determine the size of sediment that could be transported given a certain flow. (See Appendix C.) Incipient motion analysis calculates the boundary shear stress (shear stress applied due to moving water) and the critical shear stress (shear stress that causes movement of sediment). If the boundary shear stress is greater, the sediment will not transport. Likewise, if the critical shear stress is greater, the sediment is capable of transport. If the two stresses equal each other, the sediment particle is at the point to where it can transport.

Based on the channel geometry, morphology, and the hydraulic properties, it was determined that for the 2-year storm, a sediment particle the size of 48 mm or 1.9 inches has the ability to transport through our system. In addition to incipient motion analysis, we have designed the culvert conveyance system and regraded the stream so that the velocities upstream and through the proposed culvert system is greater than the existing system. By increasing the velocity of flow throughout the system, the sediment that would have clogged the existing culverts now have the ability to transport rather than settle.

6. Conclusions

The proposed culvert conveyance system has been designed to properly convey Anti-Aircraft Creek flood flows under Newport Way NW, addressing the primary goals of flood hazard reduction. However, after analyzing the final design based on the primary project goals, it has been confirmed that achieving the supplemental goals of a fish passable crossing is not possible. The project limitations and constraints make the location and slopes of the box culverts not possible for fish to migrate.

APPENDIX A: DATA COLLECTION

DATE: 8-6-12

Applied Professional Services Inc.

JOB # 2930
CLIENT: City of Issaquah
POC:

PROJECT: Newport Wy

Pothole Date	Pothole # Core #	Target Utility	Depth to top of util. In inches	Depth to Bot of util. In inches	Pipe/Conduit size inches	Pipe Material	Asphalt Thickness	Concrete Thickness	Subsurface Composition/Comments
8-6-12	1	COM	36"	37"	1"	D.B.	—	—	Hardpan + Rock
	2	H2O	Dug at	One call	Locates	and	Found		F.O. Duct. over →
	3	F.O.	40"	63"	24" wide	Concrete duct	8"	—	Hardpan + Rocky
	4	COM	24.5"	25.5"	1"	D.B.	7"	—	Rocky
	5	GAS	40"	46"	6"	STW	5"	—	Rocky
	5A	sewer	Client	said	do not	need	to dig	on	sewer pipe.
	Client	will	measure	down	in	man hole.			
	6	S.L. Power	19"	20"	1"	P.V.C.	—	—	Rocky
	7	COM	26"	27.5"	1.5"	D.B.	—	—	Rocky
	8	Tel.	No	one call	Locates	down.		Telephone	doe's not locate.
	Did not dig.	Need's	to be	Located		by	one		call
8-7-12	8	Tel.	32.5"	37"	(2) x 4"	P.V.C.	4"	—	Oo side by side + C.D.F Rocky
8-6-12	9	H2O	44"	68"	24"	DI	8"	—	Hardpan

Pebble Count Data Sheet

Area #1

Location: Down Stream of the Neighboring Fence Line

Pebble #	Size (mm)	Pebble #	Size (mm)	Pebble #	Size (mm)	Pebble #	Size (mm)
1	6	26	25	51	50	76	75
2	7	27	28	52	52	77	78
3	7	28	28	53	54	78	80
4	7	29	28	54	55	79	85
5	9	30	30	55	55	80	85
6	9	31	30	56	56	81	90
7	10	32	30	57	56	82	95
8	11	33	32	58	58	83	95
9	12	34	32	59	58	84	98
10	12	35	34	60	60	85	100
11	13	36	35	61	60	86	105
12	14	37	35	62	60	87	108
13	15	38	35	63	62	88	110
14	16	39	35	64	62	89	120
15	18	40	36	65	62	90	130
16	18	41	36	66	65	91	130
17	18	42	38	67	65	92	140
18	18	43	38	68	65	93	140
19	20	44	38	69	65	94	150
20	20	45	38	70	68	95	150
21	22	46	40	71	68	96	150
22	22	47	40	72	70	97	150
23	24	48	40	73	70	98	150
24	24	49	43	74	72	99	150
25	25	50	48	75	75	100	150

% Finer	Size (mm)
D16	18
D50	48
D84	98
D100	150+

Section #	Bankfull Width (ft)
1	11.3
2	14
3	13.6
Average	13.0

Pebble Count Data Sheet

Area #2

Location: Upstream of the Neighboring Fence Line

Pebble #	Size (mm)	Pebble #	Size (mm)	Pebble #	Size (mm)	Pebble #	Size (mm)
1	1	26	13	51	27	76	53
2	1	27	13	52	28	77	54
3	2	28	14	53	28	78	55
4	2	29	14	54	29	79	57
5	3	30	15	55	29	80	58
6	3	31	15	56	31	81	63
7	4	32	15	57	31	82	63
8	5	33	16	58	33	83	64
9	5	34	16	59	33	84	65
10	5	35	17	60	34	85	66
11	5	36	17	61	34	86	67
12	6	37	17	62	36	87	73
13	6	38	18	63	37	88	74
14	6	39	19	64	38	89	77
15	6	40	19	65	40	90	77
16	7	41	19	66	40	91	78
17	8	42	19	67	41	92	87
18	9	43	20	68	42	93	103
19	10	44	20	69	43	94	103
20	11	45	21	70	43	95	105
21	11	46	22	71	46	96	130
22	11	47	25	72	46	97	150
23	12	48	26	73	46	98	150
24	12	49	26	74	48	99	150
25	13	50	27	75	49	100	150

% Finer	Size (mm)
D16	7
D50	27
D84	65
D100	150+

Section #	Bankfull Width (ft)
1	9.6
2	9.5
3	11.9
4	12.2
Average	10.8

USGS Web Soils Suvey Soil Classification Map

USGS Web Soils Survey Summary Table

Map Symbol	Soil Description	Hydrologic Soil Group	Area in AOI (acres)	Percent of AOI (%)
AgC	Alderwood gravelly sandy loam, 8 to 15 percent slopes	B	96.8	42.83
AkF	Alderwood and Kitsap soils, very steep	B	24.2	10.71
BeC	Beausite gravelly sandy loam, 6 to 15 percent slopes	C	63.3	28.01
BeD	Beausite gravelly sandy loam, 15 to 30 percent slopes	C	37.2	16.46
EvC	Everett gravelly sandy loam, 5 to 15 percent slopes	A	4.5	1.99
		Total	226	100

APPENDIX B: HYDROLOGIC ANALYSIS

WWHM2012

PROJECT REPORT

General Model Information

Project Name:	Anti-Aircraft Creek
Site Name:	
Site Address:	
City:	
Report Date:	10/14/2015
Gage:	Seatac
Data Start:	1948/10/01
Data End:	2009/09/30
Timestep:	15 Minute
Precip Scale:	1.17
Version:	2014/02/18

POC Thresholds

Low Flow Threshold for POC1:	50 Percent of the 2 Year
High Flow Threshold for POC1:	50 Year

Landuse Basin Data
Predeveloped Land Use

Basin

Bypass:	No
GroundWater:	No
Pervious Land Use	Acres
A B, Forest, Steep	125.5
C, Forest, Steep	100.5
Pervious Total	226
Impervious Land Use	Acres
Impervious Total	0
Basin Total	226

Element Flows To:

Surface	Interflow	Groundwater

Mitigated Land Use

Basin 1

Bypass:	No
GroundWater:	No
Pervious Land Use	Acres
A B, Forest, Steep	125.5
C, Forest, Steep	100.5
Pervious Total	226
Impervious Land Use	Acres
Impervious Total	0
Basin Total	226

Element Flows To:

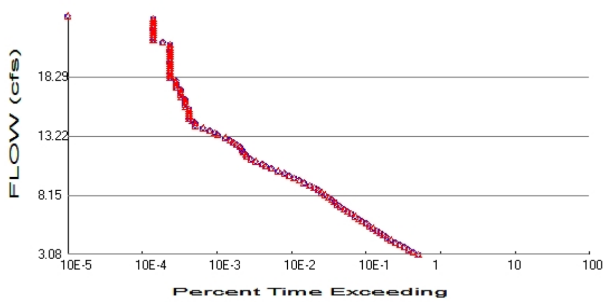
Surface	Interflow	Groundwater

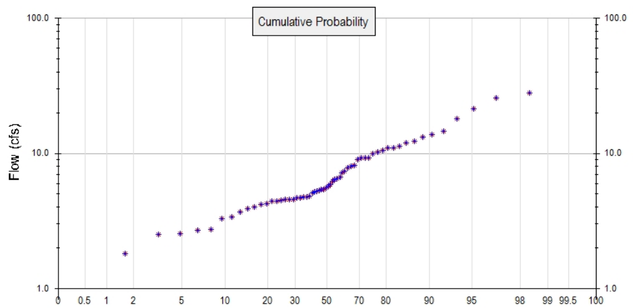
Routing Elements

Predeveloped Routing

Mitigated Routing

Analysis Results
POC 1





+ Predeveloped x Mitigated

Predeveloped Landuse Totals for POC #1
Total Pervious Area: 226
Total Impervious Area: 0

Mitigated Landuse Totals for POC #1
Total Pervious Area: 226
Total Impervious Area: 0

Flow Frequency Method: Log Pearson Type III 17B

Flow Frequency Return Periods for Predeveloped. POC #1

Return Period	**Flow(cfs)**
2 year	6.16504
5 year	10.419667
10 year	13.868914
25 year	18.982071
50 year	23.36351
100 year	28.256051

Flow Frequency Return Periods for Mitigated. POC #1

Return Period	**Flow(cfs)**
2 year	6.16504
5 year	10.419667
10 year	13.868914
25 year	18.982071
50 year	23.36351
100 year	28.256051

Annual Peaks

Annual Peaks for Predeveloped and Mitigated. POC #1

Year	**Predeveloped**	**Mitigated**
1949	8.018	8.018
1950	12.231	12.231
1951	11.022	11.022
1952	4.198	4.198
1953	3.269	3.269
1954	4.420	4.420
1955	8.132	8.132
1956	6.489	6.489
1957	6.392	6.392
1958	5.540	5.540

1959	4.549	4.549
1960	9.246	9.246
1961	4.523	4.523
1962	3.400	3.400
1963	4.428	4.428
1964	5.887	5.887
1965	4.723	4.723
1966	3.656	3.656
1967	10.963	10.963
1968	5.067	5.067
1969	5.362	5.362
1970	4.680	4.680
1971	5.365	5.365
1972	10.475	10.475
1973	4.471	4.471
1974	5.325	5.325
1975	7.829	7.829
1976	5.232	5.232
1977	2.715	2.715
1978	4.746	4.746
1979	2.557	2.557
1980	14.602	14.602
1981	3.912	3.912
1982	10.279	10.279
1983	6.246	6.246
1984	4.245	4.245
1985	2.695	2.695
1986	9.977	9.977
1987	9.217	9.217
1988	4.008	4.008
1989	2.522	2.522
1990	25.822	25.822
1991	13.215	13.215
1992	5.146	5.146
1993	4.575	4.575
1994	1.813	1.813
1995	5.751	5.751
1996	18.148	18.148
1997	11.305	11.305
1998	4.792	4.792
1999	13.836	13.836
2000	4.666	4.666
2001	1.362	1.362
2002	7.171	7.171
2003	8.941	8.941
2004	12.015	12.015
2005	7.358	7.358
2006	6.654	6.654
2007	27.796	27.796
2008	21.318	21.318
2009	9.285	9.285

Ranked Annual Peaks

Ranked Annual Peaks for Predeveloped and Mitigated. POC #1

Rank	Predeveloped	Mitigated
1	27.7956	27.7956
2	25.8219	25.8219
3	21.3176	21.3176

4	18.1482	18.1482
5	14.6015	14.6015
6	13.8356	13.8356
7	13.2151	13.2151
8	12.2306	12.2306
9	12.0146	12.0146
10	11.3051	11.3051
11	11.0222	11.0222
12	10.9632	10.9632
13	10.4745	10.4745
14	10.2794	10.2794
15	9.9768	9.9768
16	9.2848	9.2848
17	9.2459	9.2459
18	9.2173	9.2173
19	8.9414	8.9414
20	8.1322	8.1322
21	8.0178	8.0178
22	7.8285	7.8285
23	7.3584	7.3584
24	7.1714	7.1714
25	6.6540	6.6540
26	6.4894	6.4894
27	6.3924	6.3924
28	6.2457	6.2457
29	5.8869	5.8869
30	5.7506	5.7506
31	5.5395	5.5395
32	5.3649	5.3649
33	5.3618	5.3618
34	5.3252	5.3252
35	5.2323	5.2323
36	5.1464	5.1464
37	5.0673	5.0673
38	4.7921	4.7921
39	4.7462	4.7462
40	4.7229	4.7229
41	4.6798	4.6798
42	4.6660	4.6660
43	4.5746	4.5746
44	4.5494	4.5494
45	4.5226	4.5226
46	4.4710	4.4710
47	4.4275	4.4275
48	4.4203	4.4203
49	4.2453	4.2453
50	4.1985	4.1985
51	4.0085	4.0085
52	3.9118	3.9118
53	3.6559	3.6559
54	3.4001	3.4001
55	3.2687	3.2687
56	2.7155	2.7155
57	2.6953	2.6953
58	2.5570	2.5570
59	2.5224	2.5224
60	1.8134	1.8134
61	1.3617	1.3617

Duration Flows

The Facility PASSED

Flow(cfs)	Predev	Mit	Percentage	Pass/Fail
3.0825	10682	10682	100	Pass
3.2874	9169	9169	100	Pass
3.4922	7978	7978	100	Pass
3.6971	6915	6915	100	Pass
3.9020	6017	6017	100	Pass
4.1068	5251	5251	100	Pass
4.3117	4646	4646	100	Pass
4.5165	4102	4102	100	Pass
4.7214	3662	3662	100	Pass
4.9262	3309	3309	100	Pass
5.1311	2975	2975	100	Pass
5.3360	2676	2676	100	Pass
5.5408	2383	2383	100	Pass
5.7457	2130	2130	100	Pass
5.9505	1887	1887	100	Pass
6.1554	1697	1697	100	Pass
6.3603	1535	1535	100	Pass
6.5651	1353	1353	100	Pass
6.7700	1207	1207	100	Pass
6.9748	1081	1081	100	Pass
7.1797	962	962	100	Pass
7.3845	876	876	100	Pass
7.5894	803	803	100	Pass
7.7943	741	741	100	Pass
7.9991	671	671	100	Pass
8.2040	606	606	100	Pass
8.4088	545	545	100	Pass
8.6137	485	485	100	Pass
8.8186	433	433	100	Pass
9.0234	376	376	100	Pass
9.2283	318	318	100	Pass
9.4331	272	272	100	Pass
9.6380	233	233	100	Pass
9.8429	197	197	100	Pass
10.0477	172	172	100	Pass
10.2526	142	142	100	Pass
10.4574	113	113	100	Pass
10.6623	96	96	100	Pass
10.8671	86	86	100	Pass
11.0720	71	71	100	Pass
11.2769	61	61	100	Pass
11.4817	53	53	100	Pass
11.6866	52	52	100	Pass
11.8914	48	48	100	Pass
12.0963	46	46	100	Pass
12.3012	43	43	100	Pass
12.5060	39	39	100	Pass
12.7109	35	35	100	Pass
12.9157	32	32	100	Pass
13.1206	28	28	100	Pass
13.3254	22	22	100	Pass
13.5303	20	20	100	Pass
13.7352	17	17	100	Pass

13.9400	14	14	100	Pass
14.1449	11	11	100	Pass
14.3497	11	11	100	Pass
14.5546	10	10	100	Pass
14.7595	9	9	100	Pass
14.9643	9	9	100	Pass
15.1692	9	9	100	Pass
15.3740	9	9	100	Pass
15.5789	9	9	100	Pass
15.7837	8	8	100	Pass
15.9886	8	8	100	Pass
16.1935	8	8	100	Pass
16.3983	8	8	100	Pass
16.6032	7	7	100	Pass
16.8080	7	7	100	Pass
17.0129	7	7	100	Pass
17.2178	7	7	100	Pass
17.4226	6	6	100	Pass
17.6275	6	6	100	Pass
17.8323	6	6	100	Pass
18.0372	6	6	100	Pass
18.2420	5	5	100	Pass
18.4469	5	5	100	Pass
18.6518	5	5	100	Pass
18.8566	5	5	100	Pass
19.0615	5	5	100	Pass
19.2663	5	5	100	Pass
19.4712	5	5	100	Pass
19.6761	5	5	100	Pass
19.8809	5	5	100	Pass
20.0858	5	5	100	Pass
20.2906	5	5	100	Pass
20.4955	5	5	100	Pass
20.7003	5	5	100	Pass
20.9052	5	5	100	Pass
21.1101	5	5	100	Pass
21.3149	4	4	100	Pass
21.5198	3	3	100	Pass
21.7246	3	3	100	Pass
21.9295	3	3	100	Pass
22.1344	3	3	100	Pass
22.3392	3	3	100	Pass
22.5441	3	3	100	Pass
22.7489	3	3	100	Pass
22.9538	3	3	100	Pass
23.1587	3	3	100	Pass
23.3635	3	3	100	Pass

Water Quality

Water Quality BMP Flow and Volume for POC #1

On-line facility volume:	0 acre-feet
On-line facility target flow:	0 cfs.
Adjusted for 15 min:	0 cfs.
Off-line facility target flow:	0 cfs.
Adjusted for 15 min:	0 cfs.

LID Report

LID Technique	Used for Treatment ?	Total Volume Needs Treatment (ac-ft)	Volume Through Facility (ac-ft)	Infiltration Volume (ac-ft)	Cumulative Volume Infiltration Credit	Percent Volume Infiltrated	Water Quality	Percent Water Quality Treated	Comment

Model Default Modifications

Total of 0 changes have been made.

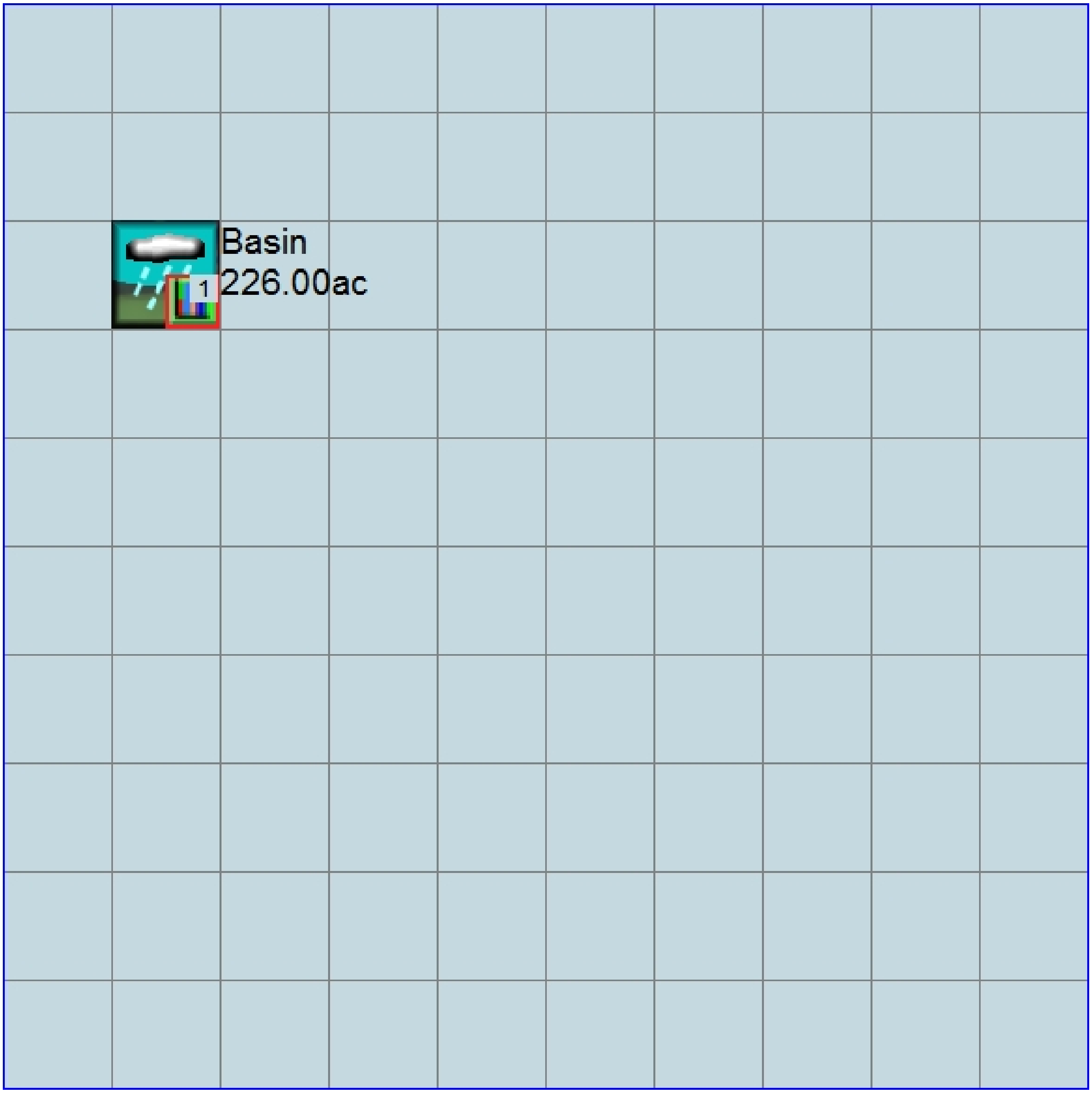
PERLND Changes

No PERLND changes have been made.

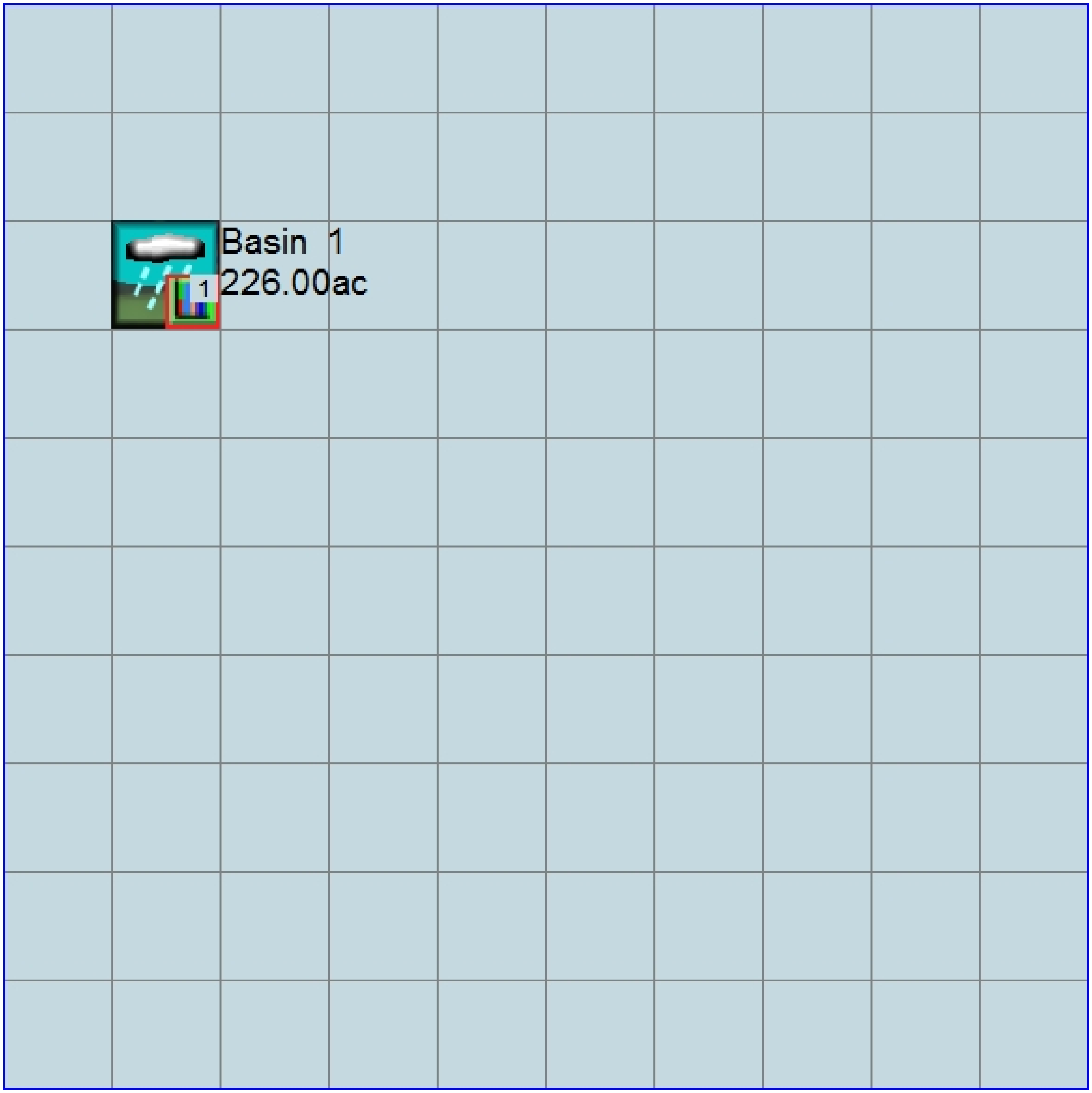
IMPLND Changes

No IMPLND changes have been made.

Appendix
Predeveloped Schematic



Mitigated Schematic



Predeveloped UCI File

```
RUN

GLOBAL
  WWHM4 model simulation
  START       1948 10 01        END    2009 09 30
  RUN INTERP OUTPUT LEVEL    3    0
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL

FILES
<File>  <Un#>   <-----------File Name------------------------------>***
<-ID->                                                              ***
WDM        26   Anti-Aircraft Creek.wdm
MESSU      25   PreAnti-Aircraft Creek.MES
           27   PreAnti-Aircraft Creek.L61
           28   PreAnti-Aircraft Creek.L62
           30   POCAnti-Aircraft Creek1.dat
END FILES

OPN SEQUENCE
    INGRP              INDELT 00:15
      PERLND       3
      PERLND      12
      COPY       501
      DISPLY       1
    END INGRP
END OPN SEQUENCE
DISPLY
  DISPLY-INFO1
    # -  #<----------Title----------->***TRAN PIVL DIG1 FIL1  PYR DIG2 FIL2 YRND
    1        Basin                       MAX                    1    2   30    9
  END DISPLY-INFO1
END DISPLY
COPY
  TIMESERIES
    # -  #  NPT  NMN ***
    1         1    1
  501         1    1
  END TIMESERIES
END COPY
GENER
  OPCODE
    #    # OPCD ***
  END OPCODE
  PARM
    #    #         K ***
  END PARM
END GENER
PERLND
  GEN-INFO
    <PLS ><-------Name------->NBLKS   Unit-systems   Printer ***
    # -  #                            User  t-series Engl Metr ***
                                            in  out           ***
    3      A/B, Forest, Steep      1    1    1    1   27    0
   12      C, Forest, Steep        1    1    1    1   27    0
  END GEN-INFO
  *** Section PWATER***

  ACTIVITY
    <PLS > ************* Active Sections *****************************
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
    3         0    0    1    0    0    0    0    0    0    0    0    0
   12         0    0    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY

  PRINT-INFO
    <PLS > ***************** Print-flags ***************************** PIVL  PYR
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC  *********
```

```
    3         0    0    4    0    0    0    0    0    0    0    0    0    1    9
   12         0    0    4    0    0    0    0    0    0    0    0    0    1    9
  END PRINT-INFO

  PWAT-PARM1
    <PLS >  PWATER variable monthly parameter value flags  ***
    # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE INFC  HWT ***
    3         0    0    0    0    0    0    0    0    0    0    0
   12         0    0    0    0    0    0    0    0    0    0    0
  END PWAT-PARM1

  PWAT-PARM2
    <PLS >      PWATER input info: Part 2         ***
    # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
    3             0         5         2       400      0.15       0.3     0.996
   12             0       4.5      0.08       400      0.15       0.5     0.996
  END PWAT-PARM2

  PWAT-PARM3
    <PLS >      PWATER input info: Part 3         ***
    # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
    3             0         0         2         2         0         0         0
   12             0         0         2         2         0         0         0
  END PWAT-PARM3
  PWAT-PARM4
    <PLS >     PWATER input info: Part 4                               ***
    # -  #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
    3           0.2       0.5      0.35         0       0.7       0.7
   12           0.2       0.3      0.35         6       0.3       0.7
  END PWAT-PARM4

  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
              ran from 1990 to end of 1992 (pat 1-11-95) RUN 21 ***
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    3             0         0         0         0         3         1         0
   12             0         0         0         0       2.5         1         0
  END PWAT-STATE1

END PERLND

IMPLND
  GEN-INFO
    <PLS ><-------Name------->   Unit-systems   Printer ***
    # -  #                     User  t-series Engl Metr ***
                                      in  out           ***
  END GEN-INFO
  *** Section IWATER***

  ACTIVITY
    <PLS > ************* Active Sections *****************************
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL   ***
  END ACTIVITY

  PRINT-INFO
    <ILS > ******** Print-flags ******** PIVL  PYR
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL    *********
  END PRINT-INFO

  IWAT-PARM1
    <PLS >  IWATER variable monthly parameter value flags  ***
    # -  # CSNO RTOP  VRS  VNN RTLI     ***
  END IWAT-PARM1

  IWAT-PARM2
    <PLS >      IWATER input info: Part 2         ***
    # -  # ***  LSUR     SLSUR      NSUR     RETSC
  END IWAT-PARM2

  IWAT-PARM3
```

```
    <PLS >      IWATER input info: Part 3         ***
    # -  # ***PETMAX    PETMIN
  END IWAT-PARM3

  IWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  RETS      SURS
  END IWAT-STATE1

END IMPLND

SCHEMATIC
<-Source->                    <--Area-->     <-Target->   MBLK   ***
<Name>   #                    <-factor->     <Name>   #   Tbl#   ***
Basin***
PERLND   3                         125.5     COPY   501     12
PERLND   3                         125.5     COPY   501     13
PERLND  12                         100.5     COPY   501     12
PERLND  12                         100.5     COPY   501     13

******Routing******
END SCHEMATIC

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
COPY   501 OUTPUT MEAN   1 1   48.4        DISPLY   1     INPUT  TIMSER 1



<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
END NETWORK

RCHRES
  GEN-INFO
    RCHRES       Name        Nexits   Unit Systems   Printer                 ***
    # -  #<------------------><---> User T-series  Engl Metr LKFG           ***
                                             in  out                         ***
  END GEN-INFO
  *** Section RCHRES***

  ACTIVITY
    <PLS > ************* Active Sections *****************************
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
  END ACTIVITY

  PRINT-INFO
    <PLS > ***************** Print-flags ****************** PIVL  PYR
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR  *********
  END PRINT-INFO

  HYDR-PARM1
    RCHRES  Flags for each HYDR Section                                      ***
    # -  #  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
            FG FG FG FG  possible  exit  *** possible  exit      possible  exit
             *  *  *  *     *  *  *  *  *       *  *  *  *  *        ***
  END HYDR-PARM1

  HYDR-PARM2
    # -  #    FTABNO       LEN     DELTH     STCOR        KS      DB50       ***
  <------><--------><--------><--------><--------><--------><-------->       ***
  END HYDR-PARM2
  HYDR-INIT
    RCHRES  Initial conditions for each HYDR section                         ***
    # -  # ***   VOL     Initial  value  of COLIND     Initial  value  of OUTDGT
          *** ac-ft     for each possible exit       for each possible exit
  <------><-------->     <---><---><---><---><---> *** <---><---><---><---><--->
  END HYDR-INIT
END RCHRES
```

```
SPEC-ACTIONS
END SPEC-ACTIONS
FTABLES
END FTABLES

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
WDM      2 PREC     ENGL    1.167          PERLND   1 999 EXTNL  PREC
WDM      2 PREC     ENGL    1.167          IMPLND   1 999 EXTNL  PREC
WDM      1 EVAP     ENGL    0.76           PERLND   1 999 EXTNL  PETINP
WDM      1 EVAP     ENGL    0.76           IMPLND   1 999 EXTNL  PETINP

END EXT SOURCES

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Tgap Amd ***
<Name>   #        <Name> # #<-factor->strg <Name>   # <Name>    tem strg strg***
COPY   501 OUTPUT MEAN   1 1     48.4      WDM    501 FLOW     ENGL      REPL
END EXT TARGETS

MASS-LINK
<Volume>   <-Grp> <-Member-><--Mult-->     <Target>       <-Grp> <-Member->***
<Name>            <Name> # #<-factor->     <Name>                <Name> # #***
  MASS-LINK       12
PERLND     PWATER SURO       0.083333      COPY           INPUT  MEAN
  END MASS-LINK   12

  MASS-LINK       13
PERLND     PWATER IFWO       0.083333      COPY           INPUT  MEAN
  END MASS-LINK   13


END MASS-LINK

END RUN
```

Mitigated UCI File

```
RUN

GLOBAL
  WWHM4 model simulation
  START       1948 10 01        END    2009 09 30
  RUN INTERP OUTPUT LEVEL    3    0
  RESUME     0 RUN     1                   UNIT SYSTEM     1
END GLOBAL

FILES
<File>  <Un#>   <-----------File Name------------------------------>***
<-ID->                                                              ***
WDM        26   Anti-Aircraft Creek.wdm
MESSU      25   MitAnti-Aircraft Creek.MES
           27   MitAnti-Aircraft Creek.L61
           28   MitAnti-Aircraft Creek.L62
           30   POCAnti-Aircraft Creek1.dat
END FILES

OPN SEQUENCE
    INGRP              INDELT 00:15
      PERLND       3
      PERLND      12
      COPY       501
      DISPLY       1
    END INGRP
END OPN SEQUENCE
DISPLY
  DISPLY-INFO1
    # -  #<----------Title----------->***TRAN PIVL DIG1 FIL1  PYR DIG2 FIL2 YRND
    1        Basin  1                    MAX                      1    2   30    9
  END DISPLY-INFO1
END DISPLY
COPY
  TIMESERIES
    # -  #  NPT  NMN ***
    1         1    1
  501         1    1
  END TIMESERIES
END COPY
GENER
  OPCODE
    #    # OPCD ***
  END OPCODE
  PARM
    #    #         K ***
  END PARM
END GENER
PERLND
  GEN-INFO
    <PLS ><-------Name------->NBLKS   Unit-systems   Printer ***
    # -  #                            User  t-series Engl Metr ***
                                            in  out         ***
    3     A/B, Forest, Steep      1    1    1    1   27    0
   12     C, Forest, Steep        1    1    1    1   27    0
  END GEN-INFO
  *** Section PWATER***

  ACTIVITY
    <PLS > ************* Active Sections *****************************
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC ***
    3         0    0    1    0    0    0    0    0    0    0    0    0
   12         0    0    1    0    0    0    0    0    0    0    0    0
  END ACTIVITY

  PRINT-INFO
    <PLS > ***************** Print-flags ***************************** PIVL  PYR
    # -  # ATMP SNOW PWAT  SED  PST  PWG PQAL MSTL PEST NITR PHOS TRAC  *********
```

```
    3         0    0    4    0    0    0    0    0    0    0    0    0    1    9
   12         0    0    4    0    0    0    0    0    0    0    0    0    1    9
  END PRINT-INFO

  PWAT-PARM1
    <PLS >  PWATER variable monthly parameter value flags  ***
    # -  # CSNO RTOP UZFG  VCS  VUZ  VNN VIFW VIRC  VLE INFC  HWT ***
    3         0    0    0    0    0    0    0    0    0    0    0
   12         0    0    0    0    0    0    0    0    0    0    0
  END PWAT-PARM1

  PWAT-PARM2
    <PLS >      PWATER input info: Part 2         ***
    # -  # ***FOREST      LZSN    INFILT      LSUR     SLSUR     KVARY     AGWRC
    3              0         5         2       400      0.15       0.3     0.996
   12              0       4.5      0.08       400      0.15       0.5     0.996
  END PWAT-PARM2

  PWAT-PARM3
    <PLS >      PWATER input info: Part 3         ***
    # -  # ***PETMAX    PETMIN    INFEXP    INFILD    DEEPFR    BASETP    AGWETP
    3              0         0         2         2         0         0         0
   12              0         0         2         2         0         0         0
  END PWAT-PARM3
  PWAT-PARM4
    <PLS >     PWATER input info: Part 4                               ***
    # -  #     CEPSC      UZSN      NSUR     INTFW       IRC     LZETP ***
    3            0.2       0.5      0.35         0       0.7       0.7
   12            0.2       0.3      0.35         6       0.3       0.7
  END PWAT-PARM4

  PWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
              ran from 1990 to end of 1992 (pat 1-11-95) RUN 21 ***
    # -  # ***  CEPS      SURS       UZS      IFWS       LZS      AGWS      GWVS
    3              0         0         0         0         3         1         0
   12              0         0         0         0       2.5         1         0
  END PWAT-STATE1

END PERLND

IMPLND
  GEN-INFO
    <PLS ><-------Name-------> Unit-systems   Printer ***
    # -  #                     User  t-series Engl Metr ***
                                     in  out            ***
  END GEN-INFO
  *** Section IWATER***

  ACTIVITY
    <PLS > ************* Active Sections *****************************
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL   ***
  END ACTIVITY

  PRINT-INFO
    <ILS > ******** Print-flags ******** PIVL  PYR
    # -  # ATMP SNOW IWAT  SLD  IWG IQAL    *********
  END PRINT-INFO

  IWAT-PARM1
    <PLS >  IWATER variable monthly parameter value flags  ***
    # -  # CSNO RTOP  VRS  VNN RTLI     ***
  END IWAT-PARM1

  IWAT-PARM2
    <PLS >      IWATER input info: Part 2         ***
    # -  # ***  LSUR     SLSUR      NSUR     RETSC
  END IWAT-PARM2

  IWAT-PARM3
```

```
    <PLS >      IWATER input info: Part 3         ***
    # -  # ***PETMAX    PETMIN
  END IWAT-PARM3

  IWAT-STATE1
    <PLS > *** Initial conditions at start of simulation
    # -  # ***  RETS      SURS
  END IWAT-STATE1

END IMPLND

SCHEMATIC
<-Source->                  <--Area-->     <-Target->   MBLK   ***
<Name>   #                  <-factor->     <Name>   #   Tbl#   ***
Basin  1***
PERLND   3                       125.5     COPY   501     12
PERLND   3                       125.5     COPY   501     13
PERLND  12                       100.5     COPY   501     12
PERLND  12                       100.5     COPY   501     13

******Routing******
END SCHEMATIC

NETWORK
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
COPY   501 OUTPUT MEAN   1 1   48.4        DISPLY   1     INPUT  TIMSER 1



<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   #        <Name> # #<-factor->strg <Name>   #   #        <Name> # #  ***
END NETWORK

RCHRES
  GEN-INFO
    RCHRES       Name        Nexits   Unit Systems   Printer                 ***
    # -  #<------------------><---> User T-series  Engl Metr LKFG            ***
                                           in  out                           ***
  END GEN-INFO
  *** Section RCHRES***

  ACTIVITY
    <PLS > ************* Active Sections *****************************
    # -  # HYFG ADFG CNFG HTFG SDFG GQFG OXFG NUFG PKFG PHFG ***
  END ACTIVITY

  PRINT-INFO
    <PLS > ***************** Print-flags ****************** PIVL  PYR
    # -  # HYDR ADCA CONS HEAT  SED  GQL OXRX NUTR PLNK PHCB PIVL  PYR  *********
  END PRINT-INFO

  HYDR-PARM1
    RCHRES  Flags for each HYDR Section                                      ***
    # -  #  VC A1 A2 A3  ODFVFG for each *** ODGTFG for each     FUNCT  for each
            FG FG FG FG  possible  exit  *** possible  exit      possible  exit
             *  *  *  *    *  *  *  *  *       *  *  *  *  *         ***
  END HYDR-PARM1

  HYDR-PARM2
    # -  #    FTABNO       LEN     DELTH     STCOR        KS      DB50       ***
  <------><--------><--------><--------><--------><--------><-------->       ***
  END HYDR-PARM2
  HYDR-INIT
    RCHRES  Initial conditions for each HYDR section                         ***
    # -  # ***   VOL     Initial  value  of COLIND     Initial  value  of OUTDGT
          *** ac-ft     for each possible exit       for each possible exit
  <------><-------->     <---><---><---><---><---> *** <---><---><---><---><--->
  END HYDR-INIT
END RCHRES
```

```
SPEC-ACTIONS
END SPEC-ACTIONS
FTABLES
END FTABLES

EXT SOURCES
<-Volume-> <Member> SsysSgap<--Mult-->Tran <-Target vols> <-Grp> <-Member->  ***
<Name>   # <Name> # tem strg<-factor->strg <Name>   #   #        <Name> # #  ***
WDM      2 PREC     ENGL    1.167          PERLND   1 999 EXTNL  PREC
WDM      2 PREC     ENGL    1.167          IMPLND   1 999 EXTNL  PREC
WDM      1 EVAP     ENGL    0.76           PERLND   1 999 EXTNL  PETINP
WDM      1 EVAP     ENGL    0.76           IMPLND   1 999 EXTNL  PETINP

END EXT SOURCES

EXT TARGETS
<-Volume-> <-Grp> <-Member-><--Mult-->Tran <-Volume-> <Member> Tsys Tgap Amd ***
<Name>   #        <Name> # #<-factor->strg <Name>   # <Name>    tem strg strg***
COPY     1 OUTPUT MEAN   1 1     48.4      WDM    701 FLOW     ENGL      REPL
COPY   501 OUTPUT MEAN   1 1     48.4      WDM    801 FLOW     ENGL      REPL
END EXT TARGETS

MASS-LINK
<Volume>   <-Grp> <-Member-><--Mult-->     <Target>       <-Grp> <-Member->***
<Name>            <Name> # #<-factor->     <Name>                <Name> # #***
  MASS-LINK       12
PERLND     PWATER SURO       0.083333      COPY           INPUT  MEAN
  END MASS-LINK   12

  MASS-LINK       13
PERLND     PWATER IFWO       0.083333      COPY           INPUT  MEAN
  END MASS-LINK   13


END MASS-LINK

END RUN
```

Predeveloped HSPF Message File

Mitigated HSPF Message File

Disclaimer

Legal Notice

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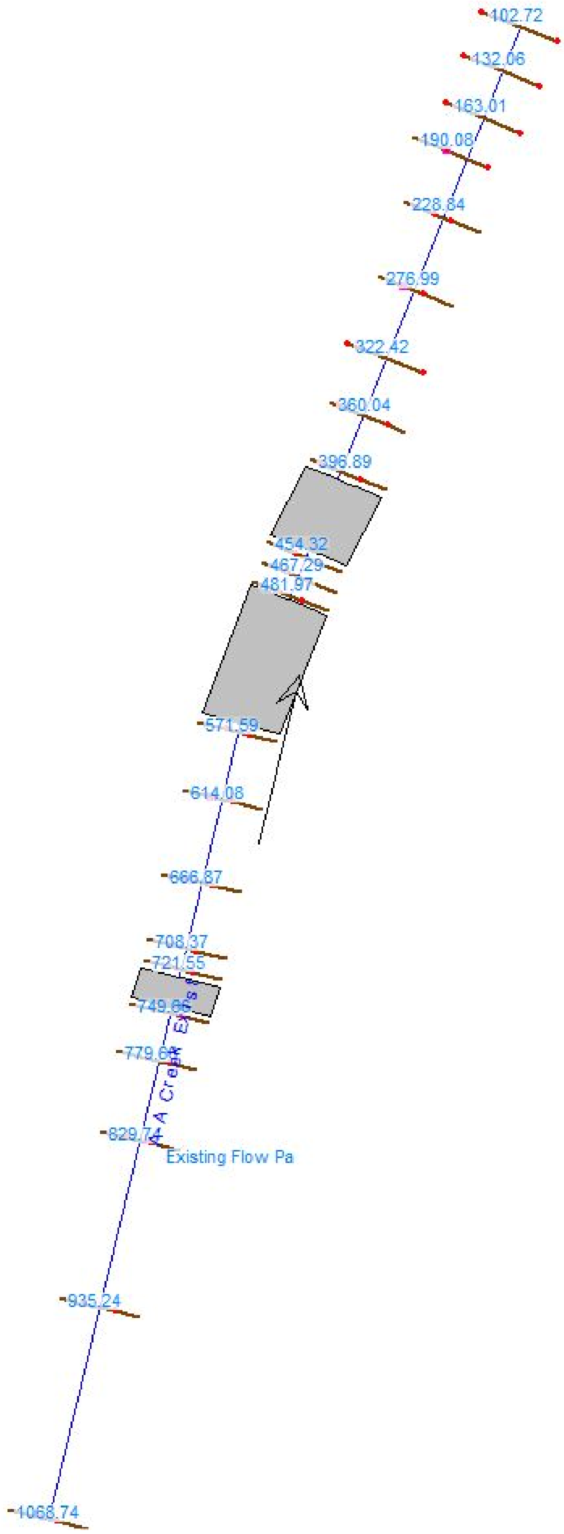
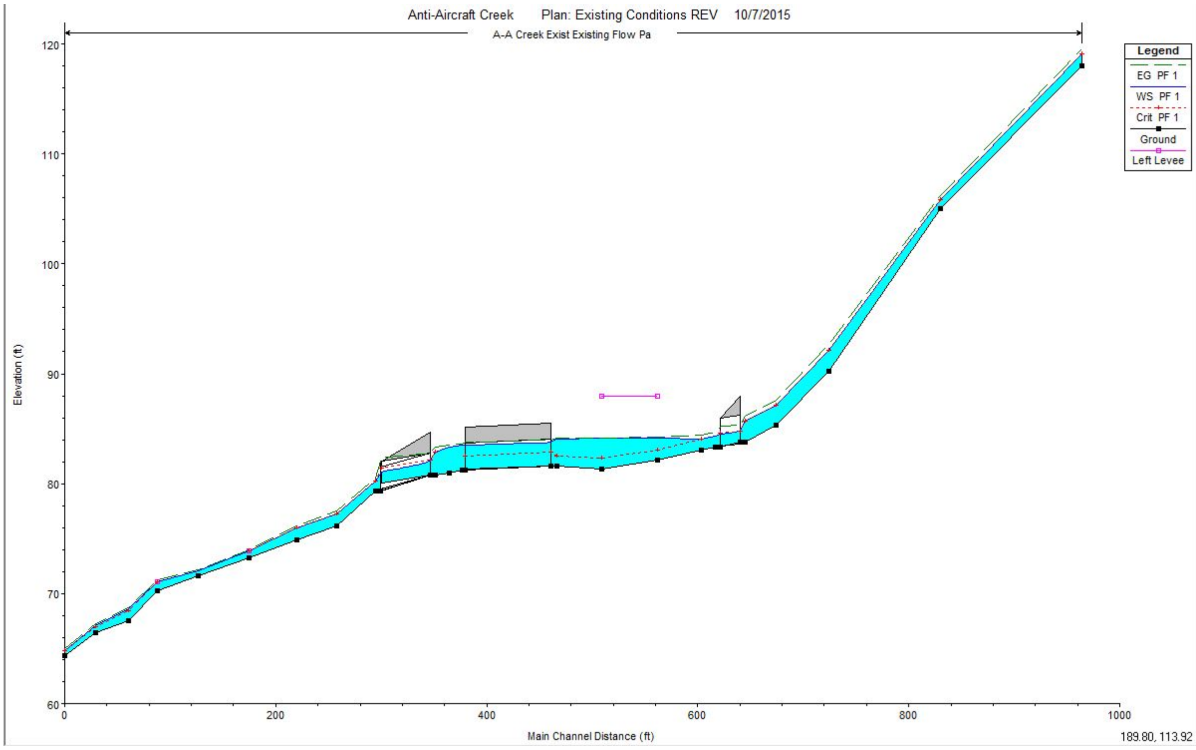
APPENDIX C: HYDRAULIC ANALYSIS



Existing Conditions HEC-RAS Plan



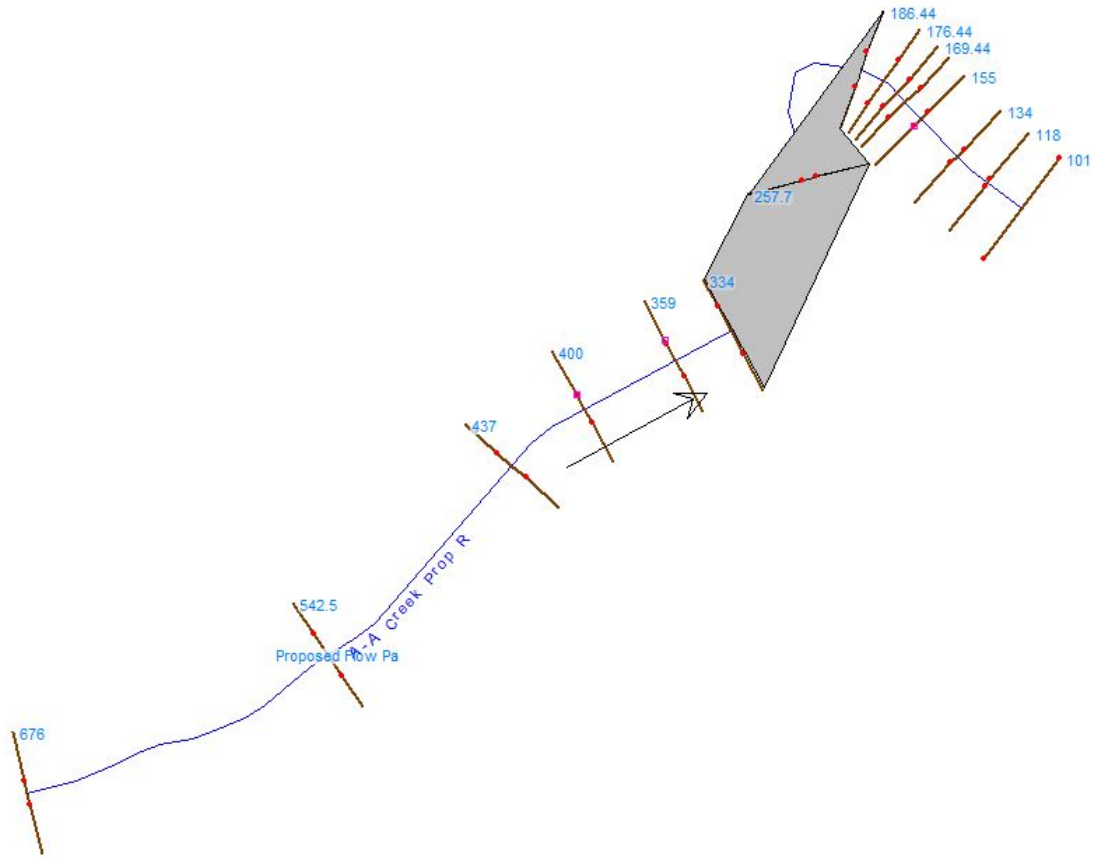
Existing Conditions Water Surface Profile

HEC-RAS Plan: Exist REV River: A-A Creek Exist Reach: Existing Flow Pa Profile: PF 1													
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Existing Flow Pa	1068.74	PF 1	28.25	118.00	119.13	119.13	119.55	0.020833	5.26	5.38	6.39	1.01
Existing Flow Pa	935.24	PF 1	28.25	105.00	105.88	105.88	106.17	0.020065	4.38	6.46	11.07	1.01
Existing Flow Pa	829.74	PF 1	28.25	90.26	92.17	92.17	92.64	0.021825	5.49	5.15	5.67	1.02
Existing Flow Pa	779.66	PF 1	28.25	85.29	87.15	87.15	87.61	0.020603	5.44	5.19	5.59	1.00
Existing Flow Pa	749.66	PF 1	28.25	83.79	85.64	85.64	86.12	0.021683	5.54	5.10	5.50	1.01
Existing Flow Pa	735		Culvert									
Existing Flow Pa	721.55	PF 1	28.25	83.35	84.35		84.65	0.013504	4.42	6.39	7.37	0.84
Existing Flow Pa	708.37	PF 1	28.25	83.10	84.08	84.04	84.44	0.016991	4.82	5.86	7.09	0.93
Existing Flow Pa	666.87	PF 1	28.25	82.11	84.13	83.06	84.20	0.001534	2.11	13.40	8.31	0.29
Existing Flow Pa	614.08	PF 1	28.25	81.36	84.11	82.31	84.15	0.000555	1.47	19.22	8.96	0.18
Existing Flow Pa	571.59	PF 1	28.25	81.59	84.08	82.53	84.12	0.000660	1.53	18.41	9.92	0.20
Existing Flow Pa	530		Culvert									
Existing Flow Pa	481.97	PF 1	28.25	81.23	83.50		83.58	0.002007	2.33	12.15	8.34	0.34
Existing Flow Pa	467.29	PF 1	28.25	80.94	83.32		83.51	0.006191	3.48	8.11	6.81	0.56
Existing Flow Pa	454.32	PF 1	28.25	80.83	82.83	82.83	83.34	0.022593	5.72	4.94	4.94	1.01
Existing Flow Pa	425		Culvert									
Existing Flow Pa	396.89	PF 1	28.25	79.31	80.21	80.21	80.51	0.019939	4.41	6.41	10.82	1.01
Existing Flow Pa	360.04	PF 1	28.25	76.18	77.25	77.25	77.53	0.020592	4.20	6.73	12.67	1.01
Existing Flow Pa	322.42	PF 1	28.25	74.93	75.96	75.96	76.18	0.022259	3.77	7.49	17.64	1.02
Existing Flow Pa	276.99	PF 1	28.25	73.29	73.91	73.91	74.02	0.018952	3.24	12.44	29.40	0.93
Existing Flow Pa	228.84	PF 1	28.25	71.60	72.11		72.15	0.010212	1.24	19.19	37.00	0.33
Existing Flow Pa	190.08	PF 1	28.25	70.25	71.03	71.03	71.24	0.094101	3.61	7.82	18.86	0.99
Existing Flow Pa	163.01	PF 1	28.25	67.54	68.61	68.45	68.73	0.041255	2.78	10.17	18.56	0.66
Existing Flow Pa	132.06	PF 1	28.25	66.41	67.09	67.00	67.23	0.057904	2.99	9.46	20.46	0.77
Existing Flow Pa	102.72	PF 1	28.25	64.38	64.82	64.82	64.98	0.105613	3.25	8.71	26.54	1.00

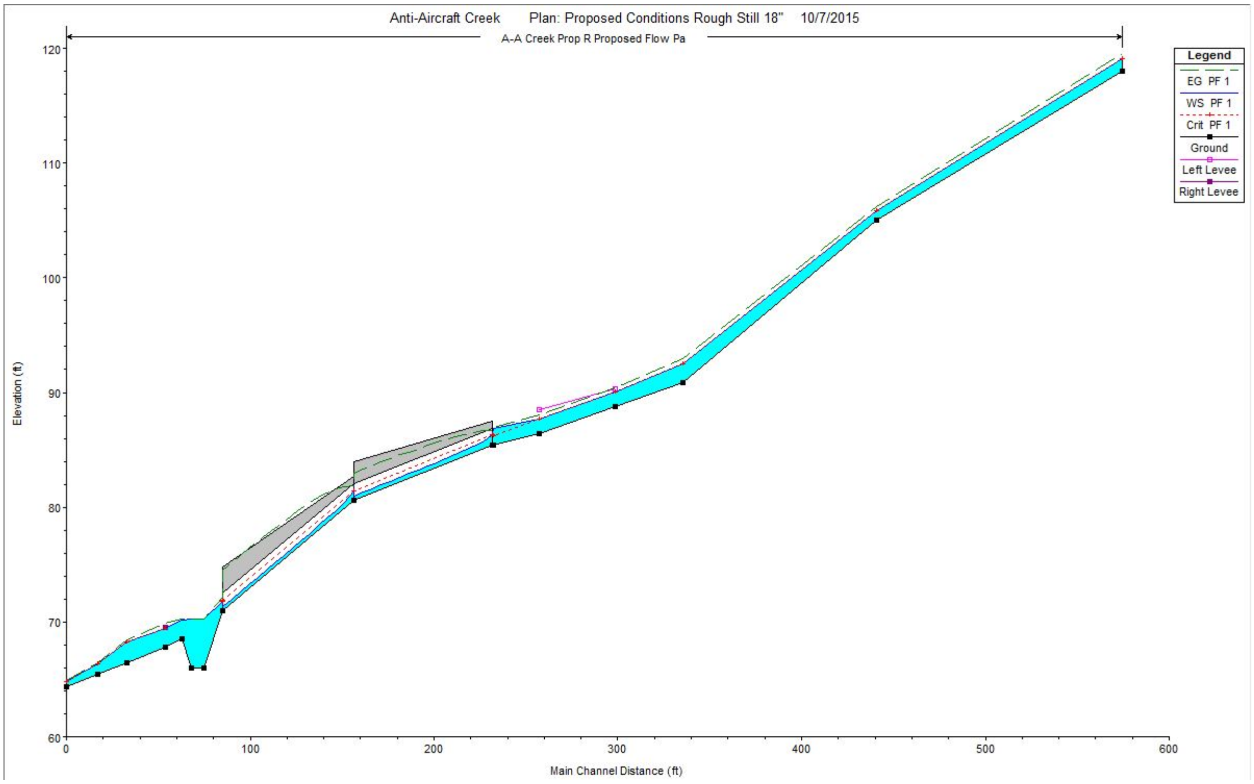
Existing Conditions Overall Results

HEC-RAS Plan: Exist REV River: A-A Creek Exist Reach: Existing Flow Pa Profile: PF 1												
Reach	River Sta	Profile	E.G. US.	W.S. US.	E.G. IC	E.G. OC	Min El Weir Flow	Q Culv Group	Q Weir	Delta WS	Culv Vel US	Culv Vel DS
			(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(ft)	(ft/s)	(ft/s)
Existing Flow Pa	735 Culvert #1	PF 1	85.64	85.64	85.44	85.64	88.01	28.25		1.29	5.91	6.58
Existing Flow Pa	530 Culvert #1	PF 1	84.12	84.08	83.60	84.12	85.49	28.25		0.59	4.00	3.94
Existing Flow Pa	425 Culvert #1	PF 1	83.05	82.83	82.93	83.05	84.70	14.13		2.62	6.24	8.98
Existing Flow Pa	425 Culvert #2	PF 1	83.05	82.83	82.92	83.05	84.70	14.13		2.62	6.24	10.59

Existing Conditions Culvert Results



Proposed Conditions HEC-RAS Plan



Proposed Conditions Water Surface Profile

HEC-RAS Plan: Sep17 River: A-A Creek Prop R Reach: Proposed Flow Pa Profile: PF 1												
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Proposed Flow Pa	676	PF 1	28.25	118.00	119.13	119.13	119.55	0.023434	5.26	5.38	6.39	1.01
Proposed Flow Pa	542.5	PF 1	28.25	105.00	105.87	105.87	106.17	0.022631	4.38	6.45	11.07	1.01
Proposed Flow Pa	437	PF 1	28.25	90.83	92.50	92.50	92.94	0.022961	5.35	5.28	6.10	1.01
Proposed Flow Pa	400	PF 1	28.25	88.73	90.07	90.07	90.41	0.021574	4.64	6.08	9.08	1.00
Proposed Flow Pa	359	PF 1	28.25	86.41	87.72	87.72	88.05	0.021448	4.57	6.18	9.43	1.00
Proposed Flow Pa	334	PF 1	28.25	85.40	86.86	86.21	86.94	0.002704	2.28	12.40	10.97	0.38
Proposed Flow Pa	325		Culvert									
Proposed Flow Pa	257.7	PF 1	28.25	80.57	81.93	81.45	82.11	0.000595	3.47	8.15	6.00	0.52
Proposed Flow Pa	190		Culvert									
Proposed Flow Pa	186.44	PF 1	28.25	71.00	71.79	71.79	72.14	0.088110	4.77	5.92	8.36	1.00
Proposed Flow Pa	176.44	PF 1	28.25	66.00	70.26		70.26	0.001012	0.58	48.32	15.58	0.06
Proposed Flow Pa	169.44	PF 1	28.25	66.00	70.25		70.26	0.001203	0.63	44.87	14.12	0.06
Proposed Flow Pa	164.31	PF 1	28.25	68.50	70.20		70.24	0.020834	1.54	18.99	23.47	0.25
Proposed Flow Pa	155	PF 1	28.25	67.79	69.44	69.44	69.85	0.088206	5.15	5.48	6.65	1.00
Proposed Flow Pa	134	PF 1	28.25	66.48	68.27	68.27	68.45	0.040791	3.70	9.87	30.28	0.69
Proposed Flow Pa	118	PF 1	28.25	65.48	66.32	66.32	66.48	0.021372	3.68	9.00	26.77	0.93
Proposed Flow Pa	101	PF 1	28.25	64.33	64.78	64.78	64.94	0.026523	3.25	8.70	26.60	1.00

Proposed Conditions Overall Results

HEC-RAS Plan: Sep17 River: A-A Creek Prop R Reach: Proposed Flow Pa Profile: PF 1												
Reach	River Sta	Profile	E.G. US.	W.S. US.	E.G. IC	E.G. OC	Min El Weir Flow	Q Culv Group	Q Weir	Delta WS	Culv Vel US	Culv Vel DS
			(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(ft)	(ft/s)	(ft/s)
Proposed Flow Pa	325 Culvert #1	PF 1	86.95	86.86	86.78	86.95	87.54	28.25		4.93	5.33	11.31
Proposed Flow Pa	190 Culvert #1	PF 1	82.12	81.93	81.89	82.12	82.66	28.25		10.14	5.33	14.32

Proposed Conditions Culvert Results

Sediment Transport Analysis

Boundary Sheer Stress

			Tauo	62.4	lb/ft^3
To	0.988416		Depth of Flow	0.72	ft
			Channel Slope	0.022	ft/ft

Dimensionless Tractive Stress

			Tauo	62.4	lb/ft^3
Te	0.06096		Spec. Grav Material	2.65	
			Spec. Grav Water	1	
			Particle size	0.15748	ft

Shear Velocity

			To	0.988416	lb/ft^3
U	0.713788		Water Mass Density	1.94	

Boundary Reynolds Number

			kinematic Viscosity	1.06E-05
Re	10624.53		U	0.713788
			Particle Size	0.15748

Dimsenionless Critical Tractive Stress

T*	0.06	From shields diagram

T*	0.06	Particle Transports
Te	0.06096	

APPENDIX D: STILLING BASIN

USBR TYPE III STILLING BASIN
Designed from the USDOT HEC No. 14, "Hydraulic Design of Energy Dissipators for Culverts and Channels"

StreamFlow			
Discharge	Q	28.26	cfs

Culvert			
Width	B	6	ft
Depth	D	2	ft
Manning's n	n	0.017	-
Slope	So	0.1194	ft/ft
Outlet IE	Zo	71	ft
Vout	Vo	14	ft/s
Flow depth	Yn	0.33	ft

Downstream Channel (Trapezodial)			
Width	B	6	ft
Bank Slope	Z	1V:2H	ft/ft
Manning's n	n	0.035	-

Step 1) Determine Froude Number at Culvert Discharge

Fr	4.29		Subcritical	Equation 8.1

Step 2) TW Velocity and Depth — From HEC-RAS Model

Vout	14	ft/s	Velocity Out of Culvert
Yn	0.33	ft	Depth of Flow out of Culvert

Step 3) Conjugate Depth

C	1	-	Pre-Determined Coefficient	
Y2	1.846	ft	Y2 > Yn -- Requires Basin	Equation 8.4

Step 4) Basin Enterance Characteristics

Z1	66	ft	Elevation at bottom of Basin		Y1 0.2 ft
St	0.5	ft/ft	Slope Transition		-0.2852 Solving Cubic to equal 0
Ss	0.5	ft/ft	Slope Leaving Basin		
Lt	10	ft	Transition Length		
Y1	0.2	ft	Flow Depth on Transition	(see above right)	From Equation 8.2
V1	23.55	ft/s	Velocity on Transition		
Fr1	9.28		Froude Number on Transition		

Step 5) Conjucate Depth

C	1	-	Pre-Determined Coefficient
Y2	2.527	ft	Flow Depth Sill (end of flat basin before transition up)
Lb/Y2	2.7	-	From Chart (Figure 8.2)
Lb	6.822	ft	Length of Basin
Ls	4.83	ft	Distance between Sill and end of Transition
Z3	68.41	ft	Elevation of Basin at exit

Tailwater Check

Z2+Y2	Z3+TW	
68.52668461	68.74479	Good

Step 6) Radius of Curvature for Still Entrance

Rc	3.89	ft	By Equatin 8.8

Step 7) Basin Elements

Chute Blocks

h1	0.2	ft	Height of the Chute Blocks
# blocks	15	-	Number of Blocks (Equation 8.9)
Width	0.2	ft	Block Width (Equation 8.10)

0.2 ft width blocks with 0.2 ft of space between each block and 0.1 ft between wall/block

Baffle Blocks

h3	0.428	ft	Height of the Baffle Block (Equation 8.11)
# blocks	9.35	10	Number of Blocks (Equation 8.12)
Width	0.3	ft	Block Width (Equation 8.13)

0.3 ft width blocks with 0.3 ft of space between and 0.15 ft between wall/block

Distance Between DS Face of Chute Block and US Face of Baffle Block

d	2.021	ft

End Sill

h4	0.307	ft	(Equation 8.14)

V Out	5.26	ft/s	Manning's Equation